Animal behavior. Chicks with a number sense

Brugger, P

DOI: https://doi.org/10.1126/science.aaa4854

Science, 30 January 2015, Vol. 374 (issue 6221): 477-478

Chicks with a number sense

In humans, the direction of the mental number line depends on directional reading habits. Newborn chicks align increasing magnitudes from left to right, suggesting that this biological default directionality is only modulated, but not caused by cultural factors

Regardless of cultural background and mathematical training, all humans have an intuitive sense of numerosity. While we share the ability to discriminate between different sets of quantities with nonhuman animals from monkey to fish to insects (*1*), one aspect of number processing is commonly assumed to be uniquely human. It is the consistent mapping of increasing quantities along the horizontal extension of space, i.e. the construction of a "mental number line". One reason seducing researchers to assume that this particular association between ordinality and space is an invention of the human mind is its cultural modification. In cultures with a left-to-right reading and writing direction, the number line expands from left to right, but cultures with an opposite directional handling of script align numbers from right to left (*2*). Now, on page xxx of this issue, Rugani *et al.* (*3*) show that three-day-old domestic chicks associate small numerosities with the left and large with the right side of space (figure). Trained to find food behind a central panel marked with five dots, in a consecutive test phase the birds searched behind the *left* of two laterally placed panels when each contained two elements, but behind the *right* when they depicted eight. However, after training with a numerosity of twenty, eight elements initiated a *left*ward search. These findings suggest the existence of a mental number line in the chick's mind. Small numbers are represented to the left of larger numbers, but whether a quantity is "small" or "large" is determined by a variable, situation-dependent standard.

The work by Rugani et al. is important in several respects. First, it adds to a growing literature on core numerical competencies in species that lack linguistic capabilities and symbolic thought. Against a commonly accepted view, language is no prerequisite for a reliable representation of discrete quantities larger than 3. Field studies of avian behavior have illustrated the evolutionary advantage of a common appreciation of numerosities across spatial, temporal and numerical domains. A particularly revealing model system is that of brood parasites such as cowbirds. Females of this species have to locate, observe and re-find the exact spatial location of host nests (*4*). In parallel, they have to synchronize their own egg laying with the host's incubation onset by keeping track of the daily increase in clutch size. Typically selected hosts produce 1 egg daily to reach a maximum of 8 eggs (*5*). Cowbirds' reproductive success thus depends on their ability to jointly represent magnitudes in space, time and number. At least with respect to space and numerosity the experiments reported here with only day old domestic chicks support the view that a general magnitude system may be functional at birth. Recent experiments with human neonates are compatible with this notion; infants age 8 hours to 3 days were found to systematically relate increases in numerical magnitude with those in spatial extent and temporal duration (*6*).

A more specific insight from the work by Rugani *et al.* is that a chick's sense for ordinality aligns increasing magnitudes from left to right. This finding allows falsification of several proposals as to the origin of mental number lines. Obviously, reading/writing direction

cannot be the ultimate cause of directionality nor can finger counting habits or other instances of "manumerical" cognition (*7*). Presumably, the predominant role of the right hemisphere for numerical ordering (*8*) asymmetrically biases initial attention to the left side of both physical and number space. Together with a preference for increasing over decreasing order - already apparent in four-month-old human infants (*9*) – the biological default of a number line would represent increasing magnitudes from left to right. Chicks' flexibility in classifying numerosities as “small” or “large” is in direct analogy to the relativity of number magnitude in the human brain. Neurological patients, who neglect the left side of space are also impaired in processing numerals located to the left of a given standard (*10*; see the figure). It is the flexible classification of extents, amounts and magnitudes as "left-sided" or "right-sided" that may have allowed for situational and possibly cultural variations in the directionality of number lines.

Rugani et al. offer a key lesson in how informative a simple, but elegantly designed behavioral experiment with a precocious species can be for the interpretation of number-space associations in the human mind. They provide a provocative set of hypotheses to be tested in future research. What is the role of emotions in the spatialization of magnitudes? In both contexts of laboratory reinforcement and natural foraging *more* is commonly equivalent to *better*; does the left hemisphere’s preference for positive, approach-motivated emotions (*11*) facilitate a relatively right-sided placement of large magnitudes? What environmental or epigenetic factors have contributed to the development of a right-to-left orientation in only a minority of cultures with a horizontally organized script? Such questions need to be tackled by many disciplines jointly, including behavioral ecology, developmental psychology, comparative linguistics and a transculturally informed neuroscience (*12*).

Figure Caption

Left: Trained to find food behind a panel representing abstract number (dots differed in color and shape, but were matched for area and circumference), chicks expect food behind the left of two panels representing a smaller number, but behind the right for a larger number. In the example, the numerosity representing 8 is once smaller and once larger than the trained reference. Right: In humans, patients who neglect the left side of space after right hemisphere damage are slow in classifying 6 as smaller or larger than 7, but fast if the reference number is 5 (*10*). The representation of increasing quantities from left to right may be the biological default, only modulated, but not caused, by situational demands or cultural habits.

References

1. S. Dehaene, *The number sense* (Oxford University Press, New York, 2011)
2. S.M.Göbel, S.Shaki, M.H.Fischer, *J. Cross-Cult. Psychol.* **42**, 543-565 (2011).
3. R.Rugani, G.Vallortigara, K.Priftis, L.Regolin, *Science* **xxx**, yyy (2015).
4. D.J.White, L.Ho, G.Freed-Brown, *Psychol. Sci.* **20**, 1140-1145 (2009).
5. J.Low, K.C.Burns, M.E.Hauber, *Int. J. Avian Sci.* **151**, 775-777 (2009).
6. M.D.de Hevia, V.Izard, A.Coubart, E.S.Spelke, A.Streri, *Proc. Natl. Acad. Sci. U.S.A.* **111**, 4809-4813 (2014).
7. M.H.Fischer, P.Brugger, *Frontiers in Psychol* **2**, article 260 (2011).
8. A.Knops, K.Willmes, *NeuroImage* **84**, 786-795 (2014).
9. V.Macchi Cassia, M.Picozzi, L.Girelli, M.D.de Hevia, *Cognition* **124**, 183-193 (2012); M.D.de Hevia, L.Girelli, M.Addabbo, V.Macchi Cassia, *PLOS ONE* ***9***, e96412 (2014).
10. P.Vuilleumier, S.Ortigue, P.Brugger, *Cortex* **40**, 399-410 (2004).
11. L.J.Rogers, G.Vallortigara, R.J.Andrew, *Divided brains: the biology and behavior of brain asymmetries* (Cambridge University Press, New York, 2013)
12. S.Kazandjian, S.Chokron, *Nature Rev. Neurosci* **9**, 965 (2008).